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A Human Factors Evaluation of the Operational Demonstration Flight Inspection Aircraft

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16. Abstract

These reports describe the data collection and analysis efforts performed by the Civil Aeromedical Institute's Human Factors Research Laboratory to assist the Office of Aviation System Standards (AVN) in the human factors evaluation of the Operational Demonstration (Ops Demo) candidate flight inspection aircraft (FIA). Although there was not sufficient time to conduct an exhaustive human factors evaluation of the Ops Demo FIA, several efforts were undertaken to assist in the determination of the suitability of the proposed aircraft for integration of flight inspection equipment and performance of the flight inspection mission. These efforts included an evaluation of flight inspection pilot and technician preferences for certain aircraft characteristics, an evaluation of aircraft cabin noise levels, an anthropometric familiarization for flight inspection pilots and technicians participating in the Ops Demo, and an evaluation of the proposed flight inspection workstation design for the medium-size, medium-range (MSR) aircraft.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

These reports describe the data collection and analysis efforts performed by the Civil Aeromedical Institute's Human Factors Research Laboratory to assist the Office of Aviation System Standards (AVN) in the human factors evaluation of the Operational Demonstration (Ops Demo) candidate flight inspection aircraft (FIA). Although there was not sufficient time to conduct an exhaustive human factors evaluation of the Ops Demo FIA, several efforts were undertaken to assist in the determination of the suitability of the proposed aircraft for integration of flight inspection equipment and performance of the flight inspection mission. These efforts included an evaluation of flight inspection pilot and technician preferences for certain aircraft characteristics, an evaluation of aircraft cabin noise levels, an anthropometric familiarization for flight inspection pilots and technicians participating in the Ops Demo, and an evaluation of the proposed flight inspection workstation design for the medium-size, medium-range (MSR) aircraft.

The Ops Demo was conducted to allow for a quantitative and qualitative evaluation of the performance, safety, and utility of each of the candidate aircraft. In addition to the evaluation of the operational utility of the aircraft by the Federal Aviation Administration (FAA) and user personnel, the Ops Demo also provided various engineering disciplines tasked by AVN to support the Source Evaluation Board's technical proposal evaluation an opportunity to physically examine the aircraft to answer or clarify any technical questions or concerns that may arise during the technical proposal evaluation. These disciplines included, but were not limited to, Human Factors, Avionics Engineering and Maintenance, Systems and Airframe Engineering, Flight Safety, and Flight Inspection. Evaluators from these disciplines provided their own evaluation plans and data sheets, and provided separate reports of their findings. This report details the findings of the human factors evaluation conducted by the FAA Human Factors Research Laboratory (AAM-510).

One of these efforts involved the assessment of the preferences of flight inspection pilots and technicians for various characteristics of the flight inspection aircraft. These results were then presented to the evaluators, allowing them to compare their preferences to those of their peers. Ops Demo test events were developed for those items of the survey most preferred by the raters and not covered by other test events. Test-cards were constructed as guides for these test events.

An assessment of the extent to which the Ops Demo pilots and technicians conformed to the anthropometric specifications of the flight inspection aircraft was also performed. Measures were collected on sitting height, eye height, leg length, arm reach, and shoulder breadth. These measurements were provided as information to the evaluators, so they would know how their personal characteristics compared to the population of interest. Data indicated that the pilots and technicians selected to perform flightdeck and workstation evaluations were generally representative of the aviator population. However, the military aviator population represented in the anthropometric distributions of the Military Standards is comprised of only men, and they appear to be taller than the FIA user population. Perhaps in future FIA procurements it would be appropriate to consider using a population more representative of the AVN pilot and technician population, rather than the military aviator population, for setting anthropometric specifications.

Additionally, an acoustic analysis was conducted of the cabin environments of three currently used MSR flight inspection aircraft and the three Ops Demo aircraft. The King Air and Sabre Liner were the noisiest of the aircraft tested. The British Aerospace Engineering aircraft was the quietest of the current flight inspection aircraft tested. The candidate large-size, long-range (LSR) aircraft was 10 dB(A) quieter, on the average, than either the candidate MSR aircraft or the candidate multi-mission (MM) aircraft. It appears likely that the candidate LSR aircraft would meet the flight inspection aircraft specifications regarding noise levels. The MM and MSR aircraft were rated acceptable; however, due to the requirement for major changes in the interior configurations to meet operational specifications, further and more detailed analyses will be required.

Finally, an evaluation of the candidate MSR aircraft technician's workstation was performed with the assistance of the Ops Demo technician evaluators. Several points of consideration were raised before the workstation layout and cabin environment became fixed. These suggestions led to major modifications in the layout of the technicians workstation. These design changes were implemented into the contractor's design proposal for the LSR aircraft; however, workstation design optimization for the LSR aircraft cabin layout has not been proposed. It is hoped that these modifications will facilitate more efficient and comfortable operation of the flight inspection equipment.

HUMAN FACTORS SURVEY OF AIRCRAFT CHARACTERISTIC PREFERENCES OF FLIGHT INSPECTION PILOTS AND TECHNICIANS

INTRODUCTION

A survey of the preferences of flight inspection pilots and technicians was conducted to assess preferences for certain characteristics of the flight inspection aircraft. Several flight inspection pilots and technicians were recruited as subject matter experts (SMEs) to develop items suitable for inclusion in the survey. The SMEs generated lists of characteristics they considered important for the candidate aircraft to possess. From these lists, survey items were developed for relative weighting using the paired comparison scaling technique. With this technique, all possible pairs of items are presented and the subjects indicate which of the two items in each pair they consider to be most desirable. For N items, $N(N-1)/2$ comparisons are required. Separate surveys were developed for pilots and technicians.

The information was then compiled for presentation to the Operational Demonstration (Ops Demo) evaluators so they would know how their personal preferences compared to those of their peers. Additionally, the information was used to prepare test-cards for the Ops Demo aircraft evaluation. Test events were developed for all of the aircraft characteristics that were evaluated and test-cards were constructed for all test events. The test events developed from the survey involved movement and access issues, and were included in the operability section of the test-card handbook (Department of Transportation, 1992). Other test events included handling (ground and flight), flight, navigation, and environmental systems, flight inspection operations, and emergency procedures.

METHOD

Subjects

Subjects in this study consisted of 75 technicians and 140 pilots serving in flight inspection field offices (FIFO) in either operational, instructional or administrative positions. From this sample, 47 technicians and 108 pilots responded to a paired comparisons survey on characteristics of the aircraft cabin work environment. The response rate represents 62.67% of the technicians and 77.14% of the pilots who were mailed surveys. Two pilot surveys and one technician survey were incorrectly filled out. These were discarded from the study, resulting in 46 technician and 106 pilot surveys appropriate for inclusion in the analysis.

Materials

As shown in Tables 1 and 2, a total of 14 items related to the pilots' work environment and 22 items related to the technicians' work environment were selected to be used in constructing separate paired comparisons surveys for the technicians and pilots. The item pairs were formed using the stimulus preparation charts prepared by Lawshe and Kephart (1950), which control for side (left/right) and separation (distance between repeated stimuli).

Procedure

Individual packets were placed in envelopes addressed to each pilot or technician. These envelopes were then mailed to the individual or the individual's FIFO. Subjects were asked to complete the survey as conscientiously as possible and to return their forms in the envelope provided. Directions for completing the survey are shown in Figure 1.

Surveys were numbered and checked for errors upon receipt, and were entered into a data file for analysis. Upon completion of the data entry, a frequency count was made on each comparison for further analysis.

RESULTS

Separate data matrices were formed from the responses of the pilots and technicians. In these square matrices, the numbers above the diagonal represent the number of times the row item was selected over the column item; whereas those numbers below the diagonal correspond to the number of times the column item was selected over the row item. Frequency counts were used to generate a frequency matrix. All other matrices required for the analysis were computed from the corresponding frequency matrix.

TABLE 1
Rank Ordered *t*-scores for Items on the Pilots' Survey

Item	*t*-score
Visibility	71.19
Stable Flight	63.84
Emergency Exit	59.27
Cabin Noise	55.18
Body Movement	52.87
Chart & Equipment Access	51.28
Chart & Equipment Storage	49.85
Emergency Equipment Access	49.10
Routine Entry and Exit	46.24
Clear Path	46.08
Stand Erect	40.12
Internal Personal Storage	38.49
Block out cabin light	38.49
Life Raft	38.01

TABLE 2
Rank Ordered *t*-scores for Items on the Technicians' Survey

Item	*t*-score
Seated body movement	66.01
Emergency exit	63.66
Access to Visual Displays	62.52
Seat movement related to equipment	61.52
Access to Doc & Equip in Workstation	59.78
Emergency Equipment	58.57
Tech VHF Radio	55.22
Forward Facing Workstation	55.09
Low cabin noise	54.09
Routine Entry and Exit	52.28
Documentation & Equipment storage	51.47
Clear Path	50.67
Life Raft	49.06
Personal Storage	45.38
Lap and shoulder straps	44.24
Visual access/fuselage windows	43.97
Stand erect	43.91
Nonrestrictive headphone cables	40.42
Adjustable lumbar support	38.68
Visual Access to cockpit	38.28
Ability to block out window light	36.34
Approach plate holder	28.84

Reliability and internal consistency measures were computed for each of the surveys. Reliability was measured using a variance component model of the analysis of variance. The reliability was .92 for both the pilot's and technician's surveys which indicates a high level of reliability.

Internal consistency was measured using Kendall's (1948) circular triads coefficient of consistence. This measure indicates the consistency of a judge as he/she compares the paired comparisons. If item i is judged more important than item j, and item j is judged to be more important than item k, then, to be consistent, item i will be judged to be more important than item k.

To determine the presence or absence of circular triads, a proportion matrix was constructed by dividing each item on the frequency matrix by the number of respondents for the survey and placing a proportion of .50 on the diagonal. A circular triad matrix, consisting of 1s and 0s, is formed from the proportion matrix by substituting a 1 for each item with a proportion equal to or greater than .50, or a 0 for each item with a proportion less than .50. The coefficient of consistence is then calculated using Kendall's formula. This test yielded a coefficient of consistence of .96 for the pilots survey and .92 for the technicians survey, which indicates a fairly high level of intra-judge consistency.

Tables 1 and 2 also show *t*-scores that have been calculated for each item to demonstrate the item's rank among the other items compared. A *t*-score is a standard score that has a mean of 50 and a standard deviation of 10. It should be noted that the *t*-score is an interval measure, which has equal distances but no absolute zero. One way to view these scores is the percentage of time a particular item was selected over all other items in the list. The *t*-scores were calculated from *z* scores generated by the SPSS Descriptives command on the total frequency count for each item. The *z* score to *t*-score transformation is simply [(*z* score • 10) + 50].

FIGURE 1

Instructions to Raters

A set of characteristics has been identified to aid in the upcoming evaluation of flight inspection aircraft. It would be helpful in the evaluation to have an estimate of which characteristics were felt to be relatively more important to pilots and technicians who will be manning the aircraft. These characteristics are provided below in paired comparison form; that is, each characteristic is paired with every other characteristic.

Please read each pair of characteristics and decide which of the two is most desirable from your point of view. Make a check mark (√) in front of the characteristic you have selected. Make sure that you select one and only one characteristic from each pair. Some pairs will be more difficult to select between than others, but please make a selection for every pair. You may change your selections on any pair at any time. In general, it is best not to spend a great deal of time on any one pair, but simply to read them both, check the one that you feel is relatively more desirable from your viewpoint, and move on to the next one.

Please do not compare your selections with any other rater or discuss the rating process before all raters have completed their ratings. It is important that only your viewpoint is represented in the ratings. An example is provided below:

__ A night at the opera   √ Attend a basketball game

In the example, the rater has selected "Attend a basketball game" as being more desirable than "A night at the opera." Please note that the items are paired side by side.

Please proceed. There is no time limit, but most people finish the rating in less than 30 minutes.

DISCUSSION

Each of the Ops Demo evaluators (six pilots and six technicians) used the test-cards as guides in evaluating the test events. Separate handbooks with distinct test events were developed for pilots and technicians. These handbooks also contained a summary of the results of this survey (see Figures 2 and 3). This information was provided so that evaluators would know how their personal preferences compared to those of their peers. With this information at hand it was possible for pilots and technicians to compare their personal preferences for these characteristics to those of their peers at any time during the evaluation.

In addition to the summary results, test-cards were constructed (see Figures 4 and 5) for those items of the survey that were not covered by other previously developed test-cards if the item's T-score was greater than the mean (i.e. t-score > 50). This included 3 items for the pilots and 6 items for the technicians.

FIGURE 2

Technician Priorities

Many of you participated in a recent survey conducted by the Human Factors Research Laboratory of the Civil Aeromedical Institute. This survey was conducted to assess the preferences of flight inspection pilots and technicians for certain characteristics of the flight inspection aircraft. The survey results are presented to give you information about your peers' preferences for certain aircraft characteristics. The reliability of these values was found to be very high. The results are presented in the table that follows; however, a brief explanation of the results may assist in your interpretation. The values in the table represent the percentage of time a particular item was selected over all other items in the list. For instance, the technicians preferred "Seated Body Movement" over all other items 66 percent of the time. This is in contrast to "Ease of Deploying Life Raft," which was preferred only 49 percent of the time over all other items. As an evaluator, it is important for you to know how your personal preferences compare to those of your peers.

Seated Body Movement	66
Access to Emergency Exit	64
Access to Visual Displays	63
Seat Movement Relative to Equipment	62
Access to Documents & Equip in Workstation	60
Access to Emergency Equipment	59
Separate VHF NAV/COM Radio	55
Forward Facing Workstation	55
Low Cabin Noise	54
Routine Entry & Exit	52
Document & Equipment Storage	51
Clear Path through Cabin	51
Ease of Deploying Life Raft	49
Interior Personal Storage	45
Lap & Shoulder Straps	44
Visual Access/Fuselage Windows	44
Stand Erect in Cabin	44
Nonrestrictive Headphone Cables	40
Adjustable Lumbar Support	39
Visual Access to Cockpit	38
Ability to Block Out Window Light	36
Approach Plate Holder	29

FIGURE 3

Pilot Priorities

Many of you participated in a recent survey conducted by the Human Factors Research Laboratory of the Civil Aeromedical Institute. This survey was conducted to assess the preferences of flight inspection pilots and technicians for certain characteristics of the flight inspection aircraft. The survey results are presented to give you information about your peers' preferences for certain aircraft characteristics. The reliability of these values was found to be very high. The results are presented in the table that follows; however, a brief explanation of the results may assist in your interpretation. The values in the table represent the percentage of time a particular item was selected over all other items in the list. For instance, the pilots preferred "Visibility Out of Cockpit" over all other items 71 percent of the time. This is in contrast to "Ease of Deploying Life Raft," which was preferred only 38 percent of the time over all other items. As an evaluator, it is important for you to know how your personal preferences compare to those of your peers.

Visibility	71
Stable Flight	64
Emergency Exit	59
Cabin Noise	55
Body Movement while seated	53
Chart & Equip Access	51
Chart & Equip Storage	50
Emergency Equip Access	49
Routing Entry and Exit	46
Clear Path through Cabin	46
Stand Erect in Cabin	40
Internal Personal Storage	38
Block Out Cabin Light at Night	38
Ease of Deploying Life Raft	38

FIGURE 4

Pilot Movement and Access Test Card

Card 10-4

Movement & Access

Pilot

Test Conditions:

AC ______________________

Pilot ______________________

<u>Items to Note</u>

- Ease of body movement while seated in cockpit
- Ease of access to flight charts and navigation equipment
- Flight chart and navigation equipment storage on flightdeck

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FIGURE 5

Technician Movement and Access Test Card

Card 10-4 T

Movement & Access

Technician

Test Conditions:

AC ______________________

Technician ______________________

<u>Items to Note</u>

- Ease of body movement while seated
- Ease of visual access to displays
- Ability to move seats relative to equipment
- Ease of access to documents and equipment from workstation
- Adequate document and equipment storage
- Clear path through cabin

ANTHROPOMETRIC FAMILIARIZATION OF THE OPERATIONAL DEMONSTRATION FLIGHT INSPECTION PILOTS AND TECHNICIANS

INTRODUCTION

A human factors evaluation of the flightdeck and technician's workstation of the candidate aircraft was performed by a group of evaluators consisting of flight inspection pilots and electronics technicians from the Office of Aviation System Standards. To determine if the evaluation team members were representative of the population for which the specifications were developed, anthropometric measurements were taken of five body dimensions for each evaluator. These measurements were provided as information to the evaluators so they would know how their personal characteristics compared to the population of interest. In this study, the measurements were compared with those of the aviator population described in Military Standard 1472D (MIL-STD-1472D) to determine if the evaluators were representative of the population for which the system they evaluated was designed.

MIL-STD-1472D, which presents human engineering design criteria for military systems, contains a listing of 5th and 95th percentile anthropometric measurements for military aviators. Given that body part dimensions are distributed normally, 90% of the aviator population should have measurements that fall within those margins, with 5% being smaller and 5% being larger. Data on aviators in MIL-STD-1472D represent 1482 U.S. Army aviation personnel measured in 1970, 1549 U.S. Navy pilots measured in 1964, and 2420 U.S. Air Force flying personnel measured in 1967. It should be noted that the military aviator population represented in the anthropometric distributions of MIL-STD-1472D is comprised of only men.

METHOD

Subjects

The subjects of this study consisted of a group of 14 aircraft pilots and electronics technicians (13 males and one female) employed by the Federal Aviation Administration Office of Aviation System Standards. The subjects were fully clothed while being measured.

Materials

Subjects were seated in an office chair with a hard seat. Measuring devices included a meter stick, a 12-inch ruler, and a seamstress tape measure. Subjects were provided with a brief description of anthropometric measurements and the 5th and 95th percentile values of the aviator population for the measures being taken to familiarize them with anthropometric considerations in systems design (see Figure 6).

Procedure

Measurements were taken in inches of sitting height, eye height, leg length, arm reach, and shoulder breadth (see Figure 7). Sitting height and eye height were measured with the meter stick and ruler while the subject was seated in the chair. The meter stick was placed on the seat of the chair beside the subject extending to the top of the subject's head, and the ruler was used to gauge the top of the head and the height of the eyes with the corresponding measures on the meter stick. Functional leg length was measured with a tape measure extended from the waist to the bottom of the shoe while the subject was seated with one leg extended in front to the floor. Arm reach was measured with a tape measure from the plane parallel to the subject's back to the end of the thumb while the subject was seated with one arm extended to the front and the fingers curved down toward the thumb tip. Shoulder width was measured with a tape measure from shoulder to shoulder while the subject was seated with arms at the sides.

RESULTS

Table 3 shows the means of subject measurements compared with the 5th and 95th percentiles of measurements for the aviator population specified in MIL-STD-1472D. All of the body characteristic means fell between the 5th and 95th percentiles for the aviator population. Table 4 represents the frequency of subject measurements which occurred below the 5th percentile, between the 5th and 95th percentiles, and above the 95th percentile along with the percentage of cases represented in each category. Between 50.0% and 92.9% of the subjects' measurements fell between the 5th and 95th percentiles of those indicated for aviators in MIL-STD-1472D.

DISCUSSION

Data indicate that the subjects selected to perform flightdeck and workstation evaluations were generally representative of the aviator population. However, 21.4% and 28.6% of the subjects had Sitting Height and Eye Height measures below the 5th percentile. In addition, 50.0% of the subjects' leg lengths were between the 5th and 95th percentiles and 50.0% were below the 5th percentile. However, with respect to the latter, errors in measurement may have occurred because the subjects were fully clothed (anthropometric measurements are generally taken of subjects in underclothing), making it difficult to determine the exact location of the waistline. A possibility also exists that military aviators, on the average, are taller than FAA pilots and technicians. Perhaps in future FIA procurements it would be appropriate to consider using a population more representative of the AVN pilot and technician population, rather than the military aviator population, for setting anthropometric specifications.

FIGURE 6

Anthropometric Measurements

Evaluator____________________

Design and sizing of a system should ensure accommodation, compatibility, operability, and maintainability by the user population. Generally, design limits should be based upon a range of values from the 5th percentile for females to the 95th percentile for males for critical body dimensions, except for instances involving special populations, like the present aviator population. As an evaluator it is important for you to know how your personal characteristics compare to the population of interest.

For the body dimension listed below, the 5th percentile value indicates that 5% of the population will have values equal to or smaller than that value, and 95% will have larger values; conversely, the 95th percentile value indicates that 95% of the population will have values equal to or smaller than that value and five percent will have larger values. These values were selected to accommodate the 5th through the 95th percentile of FAA crew members specified as "aviators" in MIL-STD-1472D who have been appropriately selected and trained. The values below are in inches.

	Personal Measurement	5th Percentile	95th Percentile
1. SITTING HEIGHT	__________	33.7	38.8
2. EYE HEIGHT	__________	30.0	33.9
3. LEG LENGTH	__________	40.9	47.4
4. ARM REACH	__________	28.8	34.3
5. SHOULDER WIDTH	__________	17.0	20.7

FIGURE 7

Body Dimensions Measured

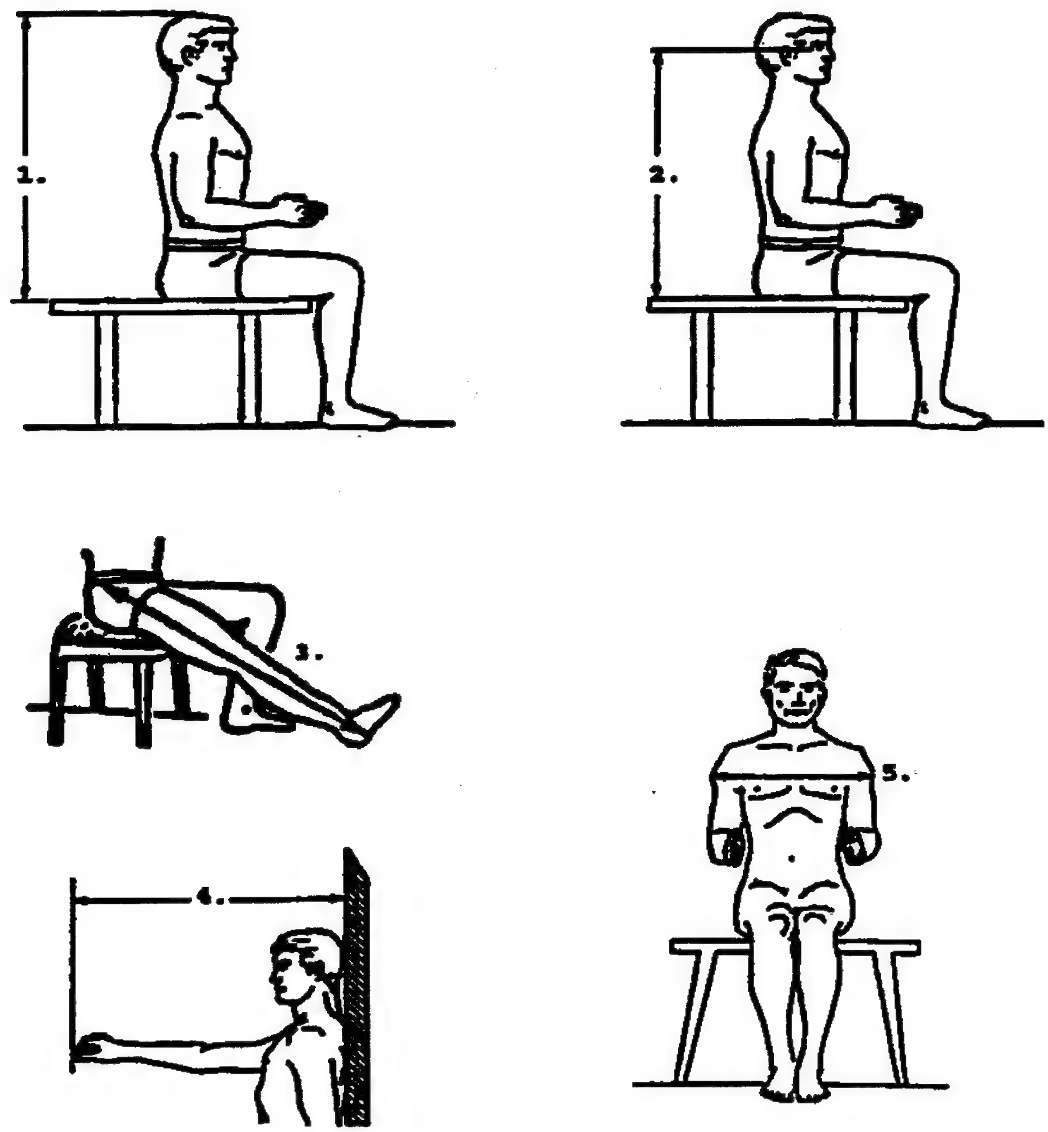


TABLE 3

Means of Subject Measurements Compared with 5th and 95th Percentile of Aviator Population (in inches).			
Body Characteristic	Mean of Subject Measurements	5th Percentile of Aviators	95th Percentile of Aviators
Sitting Height	35.3	33.7	38.8
Eye Height	31.1	30.0	33.9
Leg Length	41.7	40.9	47.4
Arm Reach	29.6	38.8	34.3
Shoulder Width	19.3	17.0	20.7

TABLE 4

Frequency and Percentage of Subject Measurements Occurring Within Percentile Ranges of Aviator Population.			
Body Characteristic	Below 5th Percentile	5th - 95th Percentile	Above 95th Percentile
Sitting Height	3 (21.4%)	11 (78.6%)	0
Eye Height	4 (28.6%)	9 (64.3%)	1 (7.1%)
Leg Length	7 (50.0%)	7 (50.0%)	0
Arm Reach	1 (7.1%)	13 (92.9%)	0
Shoulder Width	0	13 (92.9%)	1 (7.1%)

ACOUSTIC SURVEY OF THE FEDERAL AVIATION ADMINISTRATION FLIGHT INSPECTION AIRCRAFT CABIN ENVIRONMENT

INTRODUCTION

An acoustic survey of the cabin environments of three current medium-size, medium-range (MSR) aircraft used for flight inspection of navigation aids was conducted to allow for a comparison of the sound level, in dB(A), that was present. Additionally, an acoustic comparison of the three aircraft present at the Ops Demo was conducted to allow for a comparison of the noise present in these aircraft cabins. The three aircraft present at the Ops Demo were candidates for flight inspection aircraft. These aircraft included an ATR-42, the candidate multi-mission (MM) aircraft; a Canadair Challenger, the candidate long-range, large-size (LSR) aircraft; and a Lear 60, the candidate MSR aircraft.

The noise specification for the aircraft participating in the Ops Demo is a sound pressure level (spl) of less than 85 dB during all phases of flight. Furthermore, the specifications called for aural cockpit alarms to be from 5 dB to 10 dB above the ambient sound level. For any FAA employee working in an environment in which the SPL is not below an 8 hour time weighted average of 85 dB(A), enrollment in the hearing conservation program is required.

It should be pointed out that the analysis conducted will not allow for a determination of the extent to which the aircraft meet the Occupational Safety and Health Administration's (OSHA's) standards for exposure to sound levels, the type of soundproofing material that is required, speech interference characteristics, annoyance associated with the sound level present in the cabin, or the extent to which the aircraft meet FIA specifications.

However, the analysis will allow for a direct comparison between aircraft in regard to the sound level present during the selected phases of flight that are most related to hearing loss and speech interference. The (A) weighting applied to the amplitude per frequency measure of sound pressure (dB) takes into account the selective sensitivity of the human hearing mechanism to certain frequencies by appropriately weighting those frequencies to which the human ear is most sensitive at about 55 dB spl.

A more thorough investigation of the sound level present in the cabin, such as a spectral analysis, is not planned at the present time. Such an analysis would allow for determination of the extent to which sound levels with annoyance properties were present, and the type of soundproofing material required to dampen those frequencies. For a determination of the extent to which the sound level meets OSHA standards, an 8 hour dosimeter measurement of conditions present during an individual's work day would be required. A more thorough analysis will be conducted to assess the extent to which the aircraft selected for the flight inspection mission meets the FIA specifications.

METHOD

Equipment

Two dosimeters were used to assess the amplitude, in dB(A), of acoustic energy present in each of the aircraft cabins tested. The dosimeters used in the project were part of the db-301/652 Metrologger system. The db-301/652 Metrolog-ging System consists of the db-301 Metrologger, the db-652 Metroreader, and associated interconnecting cable. The db-301 is used for collecting the basic sound level data through an input device, such as a microphone. The microphone used in this project was a Metrologger mk-301R. The db-652 is the final processor and readout device (printer) of the sound level data collected by the db-301 Metrologger. After receiving the data from the db-301, the db-652 processes it and provides a printout on its internal printer. Before each test the dosimeters were calibrated using a cl-302 acoustical calibrator.

Procedure

Two experimenters collected the data from the three current aircraft; a single experimenter collected the data from the three operational demonstration aircraft. Calibration of the dosimeters took place before each test. The weather was clear with smooth air for all test flights. Upon entry into the aircraft, the make and model of aircraft was recorded. One of the dosimeter's microphones was attached to the headrest of the technician's seat or the seat nearest to the proposed location. The other dosimeter's microphone

was attached to the headrest of the pilot's seat. The microphones were attached to the seats with a clothing clip (ms-206). The serial number of the dosimeter was recorded, along with its location. The dosimeters were turned on, and the time was recorded as the engines were started. The various activities of the ensuing flight were recorded for their later correlation to the acoustic data. Data collection continued until the engines were shut down on the ramp. When the data collection was complete, the dosimeters were set to standby mode. The data were then downloaded to the db-652 Metroreader for processing and printing.

RESULTS

The db-652 Metroreader tape output was annotated with the phase of flight that was occurring at that time. Table 5 details the findings for the three current MSR aircraft and the three Ops Demo aircraft. The data in this table represent the maximum integrated sound level occurring during the phases of flight indicated. The MM landing data appear to be out of range. It is possible that the microphone was bumped or covered momentarily, causing an aberrant reading.

DISCUSSION

The King Air (KA) and Sabre Liner (SL), both current MSR aircraft, were the noisiest of the aircraft tested (Mean = 87 dB(A)). The British Aerospace Engineering (BAE) was the quietest of the current flight inspection aircraft tested (Mean = 80 dB(A)); however, the candidate LSR aircraft was quieter (Mean = 75 dB(A)). The candidate MM and MSR aircraft averaged 85 dB(A). These values are the maximum integrated sound level in dB(A) occurring across all phases of flight. They are given for comparison purposes only. The actual noise levels differed by phase of flight, as shown in Table 5. It should be noted that the interior configurations differed from aircraft to aircraft, as did the speeds at which the various maneuvers were performed. Since these maneuvers were selected for their potential to cause a higher sound level, and since they were all weighted evenly in these averages, it is likely that these values are higher than one would experience in a typical work day.

The KA, SL, and BAE were all configured with operational flight inspection interiors. The candidate LSR aircraft was configured with an executive interior and the candidate MM aircraft was configured with a commercial airline interior. The candidate MSR aircraft was unpainted, with three regular seats and a jumpseat in the cabin area. This aircraft was without an interior tube liner and had its interior insulation exposed.

It appears likely that the candidate LSR aircraft would meet the Flight Inspection Aircraft noise level specifications. On the basis of observed levels, the LSR aircraft was rated excellent, with high confidence in meeting the specifications in an operational configuration. The MM and MSR aircraft were rated acceptable, however, this is with low to moderate confidence due to the borderline noise level results (i.e. 85 dB(A)) and the requirement for major changes in the interior configurations to meet operational specifications.

TABLE 5

Peak Acoustic Energy in dB(A) for Various Phases of Flight

TYPE OF A/C	STATION	START-UP	TAXI	TAKE OFF	TRANS TO CRUISE	MAX CRUISE SPEED	SPEED BRAKE	FLAPS	STEEP APRCH	QUICK DESCENT	LOW-LEVEL FLIGHT	LANDING GEAR DOWN	LANDING	SHUT DOWN
OPERATIONAL DEMONSTRATION AIRCRAFT														
LSR	PILOT	73	72	76	80	78	83	73	N/A	75	73	77	74	75
	TECH	73	78	75	80	70	70	74	N/A	73	72	78	70	78
MM	PILOT	89	87	85	92	85	N/A	87	83	95	85	85	108*	85
	TECH	73	77	85	85	83	N/A	82	85	84	80	85	81	82
MSR	PILOT	76	78	79	85	92	92	87	84	85	80	95	82	78
	TECH	79	84	87	85	91	91	82	85	92	88	94	85	85
CURRENT MSR AIRCRAFT														
BAE	PILOT	73	70	78	81	87	85	80			81	81	85	72
	TECH	80	77	82	82	85	84	82			81	78	81	77
KING AIR	PILOT	86	96	92	87	91	N/A	86	89		86	89	96	87
	TECH	83	89	87	85	88	N/A	83	86		82	90	86	88
SABER LINER	PILOT	86	77	88	90	93	99	91			88	97	91	72
	TECH	70	83	90	91	93	99	90			88	87	87	83

MSR - Medium Range, Medium Size
LSR - Long Range, Large Size
MM - Multi-Mission
* The MM landing data appear to be out of range. It is possible that the microphone was bumped or covered momentarily, causing an aberrant reading.

HUMAN FACTORS CONSIDERATIONS OF THE MSR TECHNICIAN'S WORKSTATION

INTRODUCTION

A human factors evaluation of the candidate MSR aircraft technician's workstation was performed with the assistance of the Ops Demo technicians. These evaluations were performed in a mock-up of the flight inspection workstation contained within a mock fuselage of the candidate MSR aircraft. Several points of contention were raised for further consideration before the workstation layout and cabin environment became fixed. Many of these also apply to the candidate MM and LSR aircraft.

Points of Consideration

1. The recorder was positioned in a manner that would make it difficult to write on its associated printout. It was positioned on the left of the aircraft, requiring right-handed technicians to reach across their bodies to annotate the printout when facing the plasma display.
2. The spectrum analyzer is positioned to the lower left of the forward-facing technician's seat. It is possible to position the display for this unit at a higher level on one of the two instrument panels for easier viewing. The control unit can be located remotely.
3. No provision for storage space for equipment and documents was indicated in the mock-up. The spectrum analyzer position, if fitted with a door, would provide adequate storage. This option depends on the spectrum analyzer display and control unit being moved, as suggested above in point 2.
4. The event marker should be placed closer to the surface, instead of above the plasma display, so the arm/hand has a place to rest.
5. The cup holder location should be moved to allow for more writing space on the surface directly in front of the forward facing technician. If moved, it should not be placed where the recorder printout is annotated.
6. The corners of the workstation shelves and pullout writing surfaces should be rounded to reduce the likelihood of injury.
7. There was no indication of the headphone jack position in the mock-up. It should be positioned so as not to interfere with technician movement.
8. Windows are not proposed for installation on the right side of the aircraft cabin at the technician's workstation. It would be beneficial to provide the technician with these windows.
9. The workstation should be positioned on the opposite side of the aircraft to avoid the problem described in point 1. This would require the specification of the rigid container to be changed. The rigid container should not drive the design and layout of the technician's workstation.
10. If the recorder is moved below the plasma display, which is not recommended, it must be done so as not to cause the plasma display to be raised to an uncomfortable viewing angle.
11. The console containing the plasma display should be reduced in height to allow for forward viewing.
12. Although the revised design is considerably improved over the original design, it should not serve as a standard for other FIA systems installed in aircraft that allow for a truly forward facing work station. The current design has a forward seated console, a compromise to the specification to allow for the consideration of smaller aircraft. This design was a result of the decrease in floorspace associated with revisions in the specifications.

Based on the above considerations the contractor modified the design that had originally been proposed for integrating the flight inspection workstation into the aircraft. Each of the above points was addressed in the redesign of the revised workstation. Drawings of the original design and the design accepted by the agency are presented for comparison (Figures 8 through 11). Figures 8 and 9 detail the original aircraft cabin and technician's workstation layout, Figures 10 and 11 detail the design accepted by the agency for installation in the Lear 60 MSR FIA.

The main difference between the two layouts is the side of the aircraft on which the workstation is positioned. The original design proposal called for the workstation to be positioned on the left side of the aircraft, requiring right-handed technicians to reach across their body to annotate the recorder printout. The contractor initially did not suggest a right-handed workstation, since the size requirements for the rigid container restricted its placement in the aircraft cabin. It was suggested to AVN that the rigid container should not drive the design and layout of the technician's workstation. The rigid container specification was modified to allow for the repositioning of the workstation to the right side of the cabin. The suggestion to move the workstation to the right side of the air-

FIGURE 8

Proposed Cabin Layout

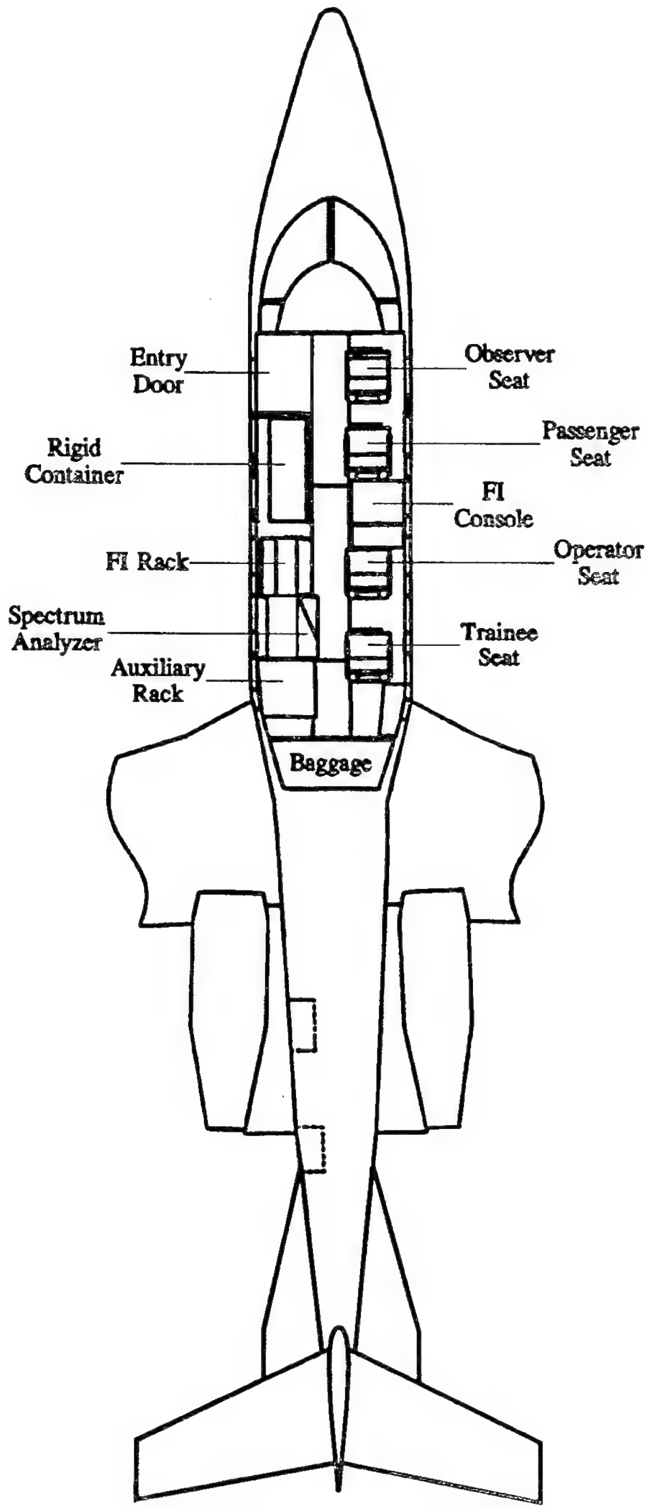


FIGURE 9

Proposed Workstation Layout

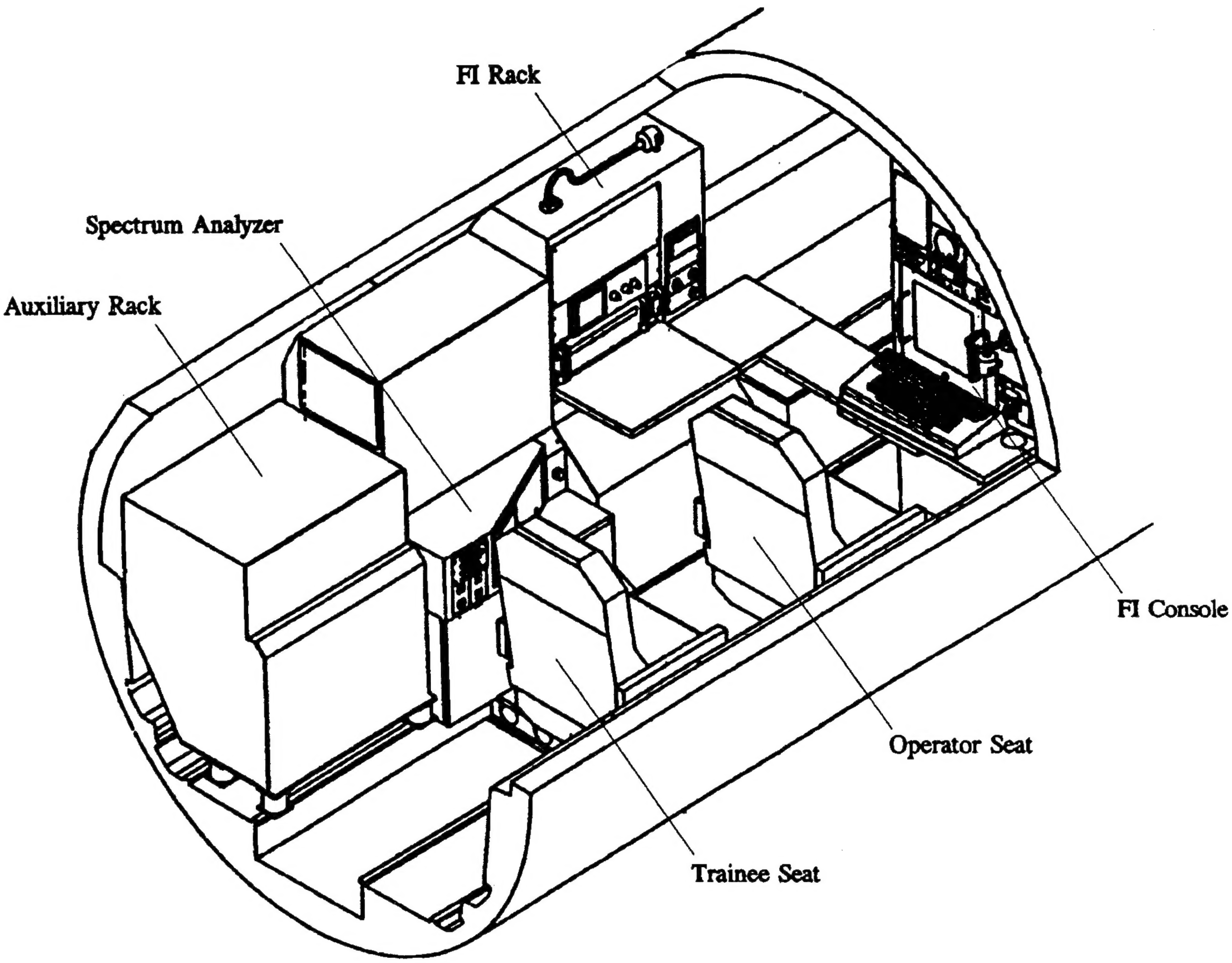


FIGURE 10

Accepted Cabin Layout

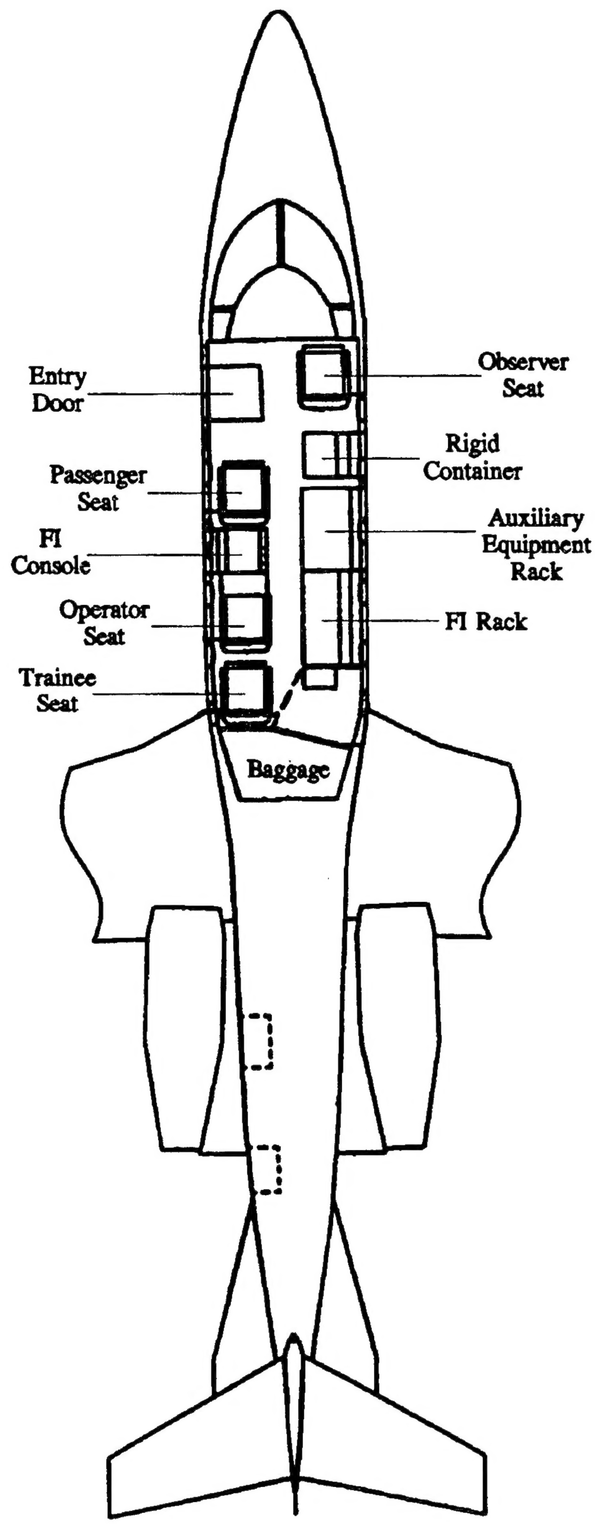
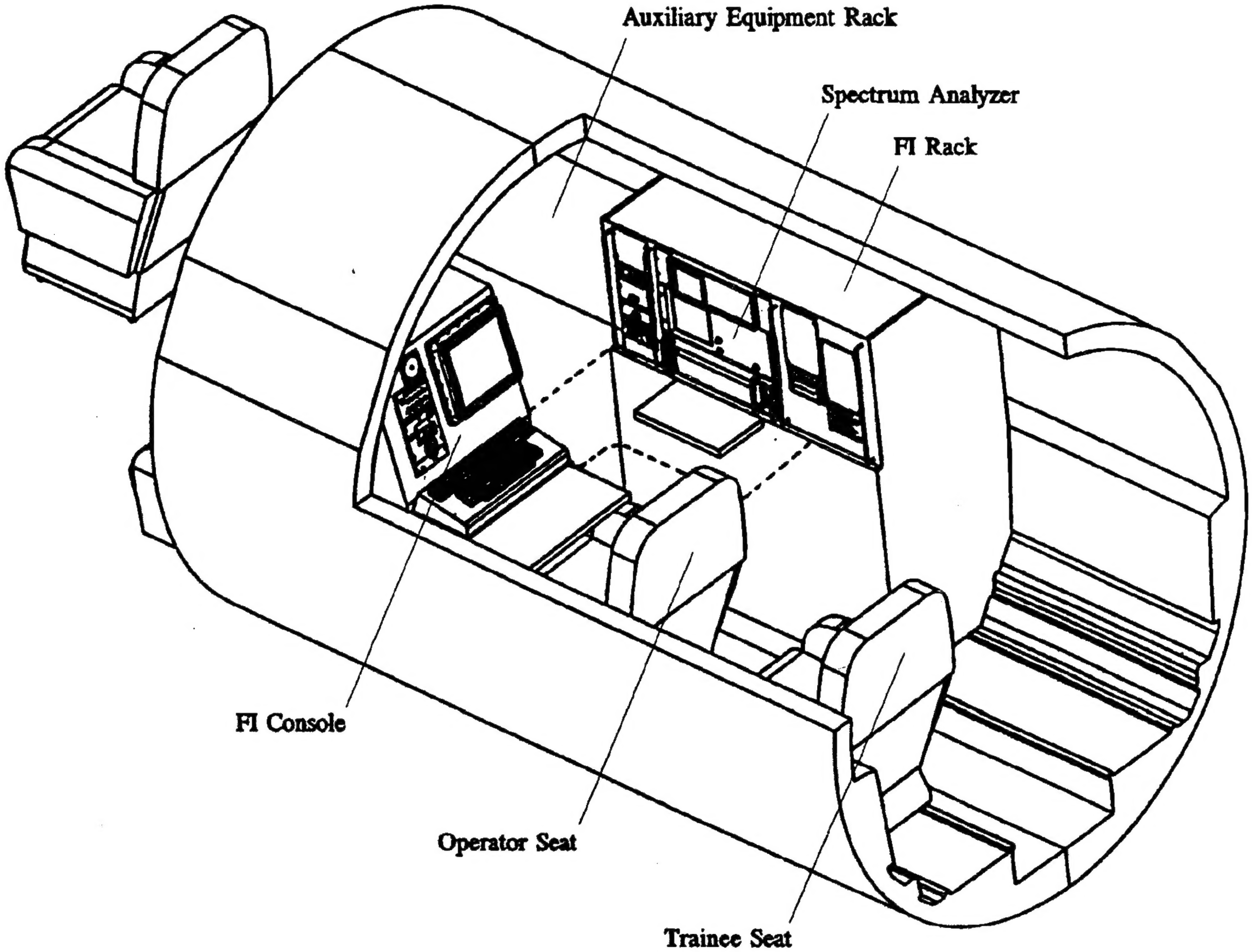


FIGURE 11

Accepted Workstation Layout



craft was incorporated into the design accepted by the agency It was contended that since the workstation had to be either right- or left-handed, it should accommodate the majority of the user population.

The only alternative to a right- or left-handed workstation was a design that incorporated the recorder/printer into the display console below the plasma display. Placing the recorder/printer below the plasma display was not acceptable for three reasons. First, the paper would spill into the technician's lap over the keyboard, making operation of the flight inspection equipment difficult. Second, the plasma display would need to be raised, potentially to an uncomfortable viewing angle. Third, it would not be possible to reduce the height of the console containing the plasma display to allow for forward viewing. The accepted design allows for forward viewing due to the reduced height of the display console.

The revised design places the spectrum analyzer in the flight inspection rack, where it can be easily viewed. The event marker was moved to a lower position near the keyboard so that the arm/hand has a place to rest. A provision was made in the display console for document storage. The cup holder was moved so that it does not reduce writing space. The edges of the workstation shelves and pullout writing surfaces were rounded to reduce the likelihood of injury. The headphone jacks were positioned to the right side of the technician's workstation. All usable windows (those not covered by flight inspection equipment) were added.

Three additional issues were raised. First, illumination provided by the proposed lighting fixtures was determined to be insufficient for meeting the specifications detailed on page 16, section 3.3.2.2.2.4 of the FIA Specification Document. Additionally, the lighting was insufficient, according to the MIL-STD-1472D. The proposed lighting provides minimal reading light for commercial aircraft. Subsequently, the contractor upgraded the lighting fixtures to meet the requirements of the FIA.

Second, the writing surface below the plotter (Figure 11) did not provide sufficient writing space for the technician. The contractor increased the size of the writing space from that shown by the solid lines to that shown by the dotted lines.

Third, the instrument pedestal between the cockpit seats provides no protection for the equipment and personnel during routine ingress and egress of the cockpit. According to the specification of the FIA on page 23, Section 3.3.3, the cockpit shall be designed using MIL-STD-1472D as a guide. In that document, Section 5.14.3 (Personnel Ingress and Egress) part .2 (Handholds and Footholds), it specifies "suitable handholds and footholds shall be supplied where necessary." Additionally, in the General Requirements Section 4.4 of MIL-STD-1472D it specifies: 4.4.i.; "Safe and adequate passageways, hatches, ladders, stairways, platforms, inclines, and other provisions for ingress and egress, and passage under normal, adverse, and emergency conditions" shall be provided. In Section 4.5 it specifies: "A fail safe design shall be provided in those areas where failure can cause catastrophe through damage to equipment, injury to personnel or inadvertent operation of critical equipment." It was suggested to AVN that a protective cover be provided for the cockpit pedestal. The contractor was then directed by AVN to design and install a protective cover for the cockpit pedestal.

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